WEDGE-SHAPED STRUCTURES IN BEDROCK AND DRIFT, CENTRAL NEW YORK STATE

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INTRODUCTION

Wedge-shaped structures resembling ice-wedge casts and fossil ice veins have been found in both bedrock and drift hosts on the eastern Appalachian Plateau of central New York. These features are exposed in the walls of four separate borrow pits at three different localities within the upper Susquehanna River drainage, south of the Mohawk Valley and northwest of the Catskill Mountains. All three localities are within Otsego County and can be found on the Milford, Richfield Springs and Mt. Vision quadrangles. The index map of figure 1 illustrates the location of each site as well as their general topographic setting. Based on their respective locations they are referred to as the Crumhorn Mountain, Fitch-Metcalf, and Laurens-Mt. Vision sites.

The purpose of this paper is to review the physical characteristics and occurrences of these wedge structures and consider what, if any, paleoclimatic significance they hold. A review of the literature indicates that previous authors have reported many features in various parts of the northeast as being related to periglacial processes. The main question under consideration is whether the structures discussed here are in any way related to permafrost processes.

A variety of permafrost and frost related features have been reported for the New England area by Denny (1951), Kaye (1960), and Koteff (1961). The work of Denny (1936), Smith (1949, 1953), and Wolfe (1953) suggest the significance of periglacial processes that once occurred in Pennsylvania and New Jersey. Clark (1968) documented the occurrence of sorted patterned ground associated with quartzite ridges from Pennsylvania to Virginia and West Virginia. Small scale bedrock deformation (up-warps) flanking vertically tapered till wedges in central New York has been reported by Cadwell (1973), and similar features in the same general area were initially interpreted to be of potential periglacial significance by Fleisher and Sales (1971). Late Wisconsin ice-wedge polygons have been reported in south western Ontario by Morgan (1972). More recently, Walters (1975) suggested polygonal patterns associated with vertically tapered ground wedges in outwash of central New Jersey to be possible ice-wedge casts. While the suggested effects of alpine glaciers and associated climatic conditions as far south as western North Carolina have been subject to contested debate since first presented by Berkland and Raymond (1973), it seems clear that a growing body of field evidence from the northeast suggests that this region may have been subjected to periglacial paleoclimate conditions of variable intensity at some time during the late glacial chronology.

WEDGE-SHAPED STRUCTURES

The terminology of the periglacial phenomena has developed over a period of decades and draws upon the nomenclature of several languages. In some cases purely descriptive terms are used, whereas others carry genetic implications. Some terms refer to only part of a three dimensional structure that has both vertical expression and a horizontal pattern, whereas others imply the entire feature. The lack of widely accepted terms with clear meaning and definite criteria for field recognition has led to confusion and independent usages. Black (1976) provided a much needed summary of terms and processes related to ice and soil wedges that will hopefully reduce problems in the future. In an effort to avoid the problem of usage and meaning, the following brief descriptions of wedge-shaped structures described by others is given. Since many of these suggest an origin through periglacial processes, it might be wise to begin at the beginning.

As suggested by Black (1966), the term periglacial is used to mean an area or region, commonly peripheral to a glacier margin, in which the climatic conditions favor intense frost action as a dominant process. While the potential for permafrost exists, it is not necessarily present. In this sense the term implies the potential for a very broad spectrum of frost related phenomena.

Ice-wedge cast

The most widely accepted term for the post-periglacial remnant of an ice-wedge (commonly considered part of a polygonal ice-wedge surface pattern) is an ice-wedge cast (Black, 1964 in Dylik 1966). Ice-wedge casts occur in association with a wide variety of host materials and represent various stages of past ice-wedge growth. Leffingwell (1919) proposed a two phase cycle of ice-wedge development controlled by the formation of frost-generated contraction cracks, in which spring meltwater carrying fine mineral matter would freeze. Summer warming resulted in the expansion of the host against the newly formed vein of ice causing lateral compression. Repeated cycles contributed to wedge growth and lateral deformation of the host. Climatic amelioration ultimately causes the ice-wedges to melt, with resulting collapse of overburden to fill the void and form a cast of the former ice wedge. Their size, shape, spacing, associated contact deformation, texture, composition, and fabric are all a function of the many parameters of ice-wedge growth and decay. Although strict criteria cannot be applied for unquestionable identification of ice-wedge casts in all possible occurrences, several authors give some characteristics which typically can be used to distinguish true ice-wedge casts from similar features that may have formed by a totally unrelated process.

Ice-wedge casts are generally 1 to 3 m wide at their tops and taper downward to depths of 3 to 4 m. Black (1976) points out that a polygon 10 to 40 meters in diameter can be anticipated, with wedges of non-uniform size ultimately forming small subdivisions.

They are commonly found in fine-textured stratified drift, but have also been reported in gravel, till and even bedrock. Stratification in the adjacent host is commonly deformed upward (Pissart, 1970a in Washburn, 1973) by lateral forces generated during ice-wedge growth or slumped downward as the result of collapse following melting (Washburn, 1973). Most often, the cast consists of a mineralogy and texture similar to the overlying material which has slumped into the void produced by melting. Portions of the adjacent host material may be incorporated and a distinctive collapse foliation may be found in poorly sorted casts (Black, 1965, 1969). The accurate interpretation of a true ice-wedge cast requires the recognition of collapse and filling from above (Johnson, 1959). In addition, Black (1976) advocates the need for supplemental "supportive evidence of permafrost", and further stresses the importance of establishing favorable meteorological conditions (limited snow, wet and cool summers) for ground ice development.

Sand-wedge

The term sand-wedge proposed by Pewe (1959), refers to a vertically oriented wedge of sand, approximately 1 meter wide and 3 meters deep, that is part of a polygonal surface pattern of shallow furrows. As with ice-wedge casts, upward marginal deformation of the host can be observed which causes them to look very similar to ice-wedge casts. However, there are several very important aspects that differ. In addition to being somewhat thinner, the filling of a sand-wedge displays much stronger vertical foliation and generally consists of much finer-grained material (Washburn, 1973). Sand-wedges require a similar thermal regime as ice-wedges but form under the restricted moisture supply of arid polar conditions. Whereas ice-wedges grow through an annual accretion of hoar-frost and summer meltwater along thermal contraction cracks, sand-wedges grow by the addition of sand grains that sift down the narrow contraction crack to form vertically oriented layers that constitute a distinct foliation (Black, 1969). No subsequent collapse occurs because no massive ice is present. A fossil sand-wedge is a true relict of a permafrost structure. The distinction between fossil sand-wedges and ice-wedge casts filled with sand or loess can be difficult and the two easily confused. (Black, 1965).

Washburn (1973) has used the term soil-wedge interchangeably with sand-wedge, which may lead to further confusion. While the purely descriptive nature of the term may at first seem appealing, it reduces the significance of the climatic implications, an important original consideration, and adds to the possible confusion with the term soil-tongue (Yehle, 1954), a feature of no periglacial significance. One possible solution would be to adopt the term ground-wedge, as suggested by Dylike (1966). This would permit the retention of the climate's significance but reduce confusion in the case of those wedges which are filled by something other than sand.

Composite wedge

An additional type of wedge, known as a composite wedge, is intermediate in form between an ice-wedge and sand-wedge, and consists of a mixture of ice and sand (Black and Berg, 1964). No known fossil forms have been reported to date, although some previously described ice-wedge casts and fossil sand-wedges may be of this type. Presumably the fill material would consist of a well foliated, fine-grained lower wedge and a somewhat more coarse-grained, collapsed upper portion. This configuration would depict an initial dry polar climate which ultimately yielded to more moist conditions. The reverse of this would result in the slump destruction of a more recent dry-climate sand-wedge as the deeper ice-wedge ultimately melted.

Soil tongue

An additional feature that is similar in form and may be confused with wedges of periglacial significance is what Yehle (1954) referred to as soil tongues. In cross-sectional view they resemble ice-wedge casts. However, inspite of their general appearance, several characteristics have been observed that serve to distinguish them from frost-related wedge forms. The outwash gravels in which they are found consist of a high percentage (65%) of carbonate lithologies (limestone and dolomite), whereas the vertically penetrating soil tongues have been leached of carbonates. In addition, stratification of the adjacent host may be traced through the tongue as an unbroken sag. Iron oxide along the tongue margins indicates the significance of chemical weathering during their formation. These characteristics and the lack of an associated horizontally continuous ground pattern suggest differential leaching and mild subsidence produced these features.

Pop-up

This rather graphic term has had limited application since first used by Cushing, et al. (1910) to describe a local form of bedrock deformation in the Thousand Islands region. A pop-up consists of fractured and tilted bedrock slabs that simulate a chevron style of buckling, broken at the crest and presumably of limited downward extent. Sbar and Sykes (1973) give a brief summary of known pop-up localities in New York State as related mainly through personal and written communication rather than published reports. Complete field descriptions are lacking except for those cases in which pop-ups have been observed to have formed in active bedrock quarries. Coates (1964) reported a case of buckling and upheaval of limestone that occurred suddenly along the floor of a quarry in Ontario. It appears as though such features can persist along trends several tens of meters long and rise in local relief several meters above the surrounding surface. The entire flexure may extend 10 to 12 m outward away from the crack. Of particular interest is the fact that the disturbed sandstone slabs that form the pop-up reported by Cushing show glacial striae and polish, which attests to their post-glacial origin. Considering the association of recent pop-ups with active quarrying, it seems reasonable to assume that they form in response to lithostatic unloading and may be expected to occur elsewhere as a result of glacial unloading.

Tension Cracks ("Tension Wedges")

Still another wedge form, similar in cross section to those reported and illustrated by many authors as ice-wedge casts, is considered by Black (1976) to be of nonthermal origin. These features have a limited width of about .5 m at their tops and thin downward to terminate at depths of 1 to 2 meters. Found in gravely outwash, they are interpreted by Black to be tension fractures in which collapse has occurred. A resulting vertical alignment of loose fill and downward deflection of adjacent beds provides the structural configuration that makes these wedge features conspicuous on quarry walls. Their isolated occurrence and lack of polygonal form are damaging characteristics to a possible periglacial interpretation.

Other alternatives

In addition to the features discussed, similar ground forms may result from a variety of processes unrelated to a periglacial regime. Various authors recognize the lateral expansion and contraction mechanism as a common result of alternate wetting and drying of expandable clays in soils. Seasonal frost action unrelated to permafrost areas is another process with the same mechanism. The most reasonable explanation for the formation of the wedge-shaped structures in Otsego County may involve one or a combination of the processes discussed. The determining factors should be the observable characteristics of each site and a consideration of other paleoclimatic indicators.

DESCRIPTION OF WEDGE STRUCTURES

Crumhorn Mountain Site (Milford Quadrangle)

Crumhorn Mountain forms the divide between the Susquehanna River and Schenevus Creek from their confluence and up valley for several miles. It has a general southwesterly trend, with glacially steepened flanks and a broad low-relief summit. Elevations along the summit generally range between 1780' and 1880' at its southern end and increase to 1900' on isolated knolls to the north. The wedge structures are located in a shallow borrow pit from which siltstone of the Oneonta formation (?) is occasionally taken by the town of Milford. The quarry includes exposures on both sides of Boy Scout Road at an elevation of approximately 1870', 1.2 miles south of Crumhorn Lake, which is situated along the mountain summit (see figure 1). A total of 14 wedge structures were well exposed along bedrock joint faces of the quarry walls at various times during normal excavation since 1970. Although several were consumed by quarry operations, several are currently well exposed, while others have been partially buried by colluvium. All wedges are oriented parallel to persistant joints sets, and it is assumed that all occur along one or the other of two dominant joint directions. The wedges are spaced at distances of approximately 6 to 10 m apart and intersect in the quarry walls to form a pattern that may be rectangular or polygonal, but cannot be seen through the shallow lodgement till that mantles the bedrock.

The wedges range from 30 cm to 1.5 m in width near the surface and taper downward to depths of 2 to 3 m where they thin to just seams. The enclosing siltstone host is sharply upturned adjacent to the wedges in a zone of marginal deformation which diminishes with depth. Slicken-sides within the deformed siltstone along bedding planes indicates displacement perpendicular to some wedge trends. The magnitude of deformation appears to be directly proportional to the thickness of the wedge and, in at least one case, involves over-turned beds near the surface. In most cases the siltstone appears warped and smoothly flexured, while others are abruptly broken into tilted slabs. Most flexed beds are highly fractured, resulting in literally hundreds of small breaks which formed perpendicular to the bedding, extending its length and giving the rock within the zone of deformation the false appearance of being longer than it actually was prior to deformation. In all cases the deformation fades laterally within a few meters of the wedge.

The wedges themselves consist of a tightly compact clastic filling of tabular rock fragments in a clay and sand matrix. The lithologies represented by the larger fragments are similar to the adjacent bed-rock and appear to be locally derived. The finer size fraction con-sists of sand and granual size erratic lithologies and minerals which were derived from the overlying lodgement till. These include frosted sand grains and lithic fragments of crystalline rocks. Each wedge displays a general vertical sorting with finer particles near the bottom and larger clasts at the top, and in many cases grain size decreases toward the wedge center. A few clearly show a thin seam of silt and fine sand down the center of the wedge when viewed in cross sections.

Two primary structures, foliation and collapse features, are clearly developed and may be significantly related to the origin of the wedges. Each is well developed but the foliation is most con-spicuous. It consists of a strong alignment of platy clasts in an orientation parallel to wedge walls. Many of these clasts appear to have been derived from the adjacent bedrock host. All clasts are firmly held in the compact wedge matrix. The collapse structure is confined to the upper portions of the wedges and generally involves down-dropped masses of overlying till. In some wedges small semi-cohesive portions of the fractured host rock appears to have subsided during collapse. Generally, the foliated and collapsed segments of a wedge reveal contrasting colors. An olive-gray color (2.5 Y 4/2) typifies the foliated lower segment, whereas a yellowish-brown color (5YR 4/4) indicates the collapsed segment. Sketches and a photo depicting the characteristics of several well developed wedges is shown in figures 2 and 3.

Fitch-Metcalf Hill (Richfield Springs Quadrangle)

This locality is situated on the broad undulating divide between Five Mile Point on Otsego Lake to the east and the flat valley floor of Fly Creek on the west, approximately midway between Cooperstown and Richfield Springs. Elevations on this portion of the divide range between 1700' and 2000', with isolated summits reaching 2,100' (see figure 1). As with the Crumhorn Mountain locality, the wedges are exposed along the walls and floor of a small, inactive rock quarry from which highly fissile siltstone and shale of the Panther Mountain formation were quarried. A think veneer of till mantles the bedrock. The excavation is located at the western end of a dirt road that connects Fitch Hill and Metcalf Hill. It consists of two adjacent but separate quarries both on the north side of the dirt road at an elevation of 1920'. The western section of the excavation contains two well developed wedges along a south-facing bedrock wall. Six smaller wedge remnants were also observed along the low walls and floor of the eastern section during the summer of 1973.

The orientation of all wedges seems to be strongly controlled by the dominant bedrock joints, which are nearly vertically inclined and trend NNE and WNW. The three major wedges are spaced 10 - 15 m apart and do not intersect. Because no surface expression could be found in the overlying till it is assumed that the plan view pattern would probably display the rectangular orientation of bedrock joints.

The two major wedges are similar in appearance and overall character to those previously described for the Crumhorn Mountain Site. They exist within the interbedded sandstone and siltstone of the Panther Mountain formation, which is flexed and broken along the same style and scale as those previously described. In addition, the fillings consist of a coarse clastic assemblage of local bedrock fragments in a tight matrix similar to the matrix of the overlying till. Figure 4 illustrates the upper portion of one of the larger wedges found at this site. Based on the similarity of these wedges with those on Crumhorn Mountain, it is assumed that the same mechanism of formation was active in both localities and probably at the same time.

Laurens-Mt. Vision Sites (Mt. Vision Quadrangle)

Otego Creek flows through a broad valley in a south-southwesterly direction as the major drainage way on the Mt. Vision quadrangle. Valley walls are oversteepened in places as the result of glacial modification and are mantled by a veneer of lodgement till that is generally fairly thin. The broad flood plain of the valley is lined by semi-continuous paired terraces with an elevation of 1160' at the village of Laurens. Otego Creek meanders across a flood plain of variable width, undercutting terrace scarps of stratified drift in some places. Well logs (Randall 1972) indicate a subsurface stratigraphy of terrace sand and gravel overlying clay in lateral valley positions, and a dominance of clays and silts along the medial segment of the valley. Total thickness of drift is not accurately known from borings, but gravity data and projected cross-valley profiles (Gieschen, 1974) suggest bedrock to lie at depths on the order of 100 to 150 feet below present stream level.

It is within these deposits that two separate gravel pits have been semi-continuously worked between the villages of Laurens and Mt. Vision. The excavation of both localities has exposed an additional type of wedge-shaped structure at what is referred to as the Laurens-Mt. Vision site.

The Laurens site is situated between Route 205 and Otego Creek, .9 miles northeast of Laurens along a flat-crested linear land form 1/4 mile southwest of a prominent kettle. The excavation is within moderately to poorly sorted topset beds of a "delta terrace" at an elevation of 1160 feet. The host material consists of interbedded coarse sand, pebbly sand, and sandy gravel 3 to 4 m thick. Fluvial sedimentary structures include cut and fill, channel deposits, cross bedding and graded bedding. Foreset beds of better sorted but similar material lie below and a thin veneer of reddish-brown silt lies above. Seven separate wedge structures were observed at various stages of excavation at this site. They extended to depths of 1 to 2 m in a vertical to steep orientation. They taper downward from widths of 5 to 15 cm at their tops. A downward deflection of bedding at their margins indicates collapse occurred. This is further shown by the subsidence of surficial silt, which appears to have been illuviated downward giving the wedge a brownish color in contrast to the gray host. The pebbles and cobbles of the wedge fillings show a distinct fabric that parallels the overall structure. Bifurcation into compound wedges was also observed. The sketch in figure 5 characterizes the salient aspects of these wedges.

No surface expression could be seen and, as far as could be determined by excavation, the wedges were not part of a polygonal pattern. Their plan view orientation was in a general northerly trend.

The Mt. Vision site is located on the western side of Otego Creek one mile south of the village of Mt. Vision. It is situated within a segment of a deltaic feature that protrudes eastward across the flood plain, constricting the valley floor. For this reason it may be interpreted as a delta moraine, but associated hummocky terrain is lacking. Possibly, delta-kame would be a reasonable alternative. Its broad upper surface lies at an elevation between 1160 and 1180 feet. At various stages of excavation strongly developed, moderately sorted, foreset beds and less well sorted topset beds 6 to 8 m thick were exposed.

Eight wedge structures have been exposed in the upper wall of this gravel quarry over the past several years. However, in almost all cases the exposures were short-lived and consumed by further excavation. In many respects the wedges here are of the same size, scale, description, orientation, and general occurrence as those previously discussed at the Laurens site. One notable exception was a single wedge structure of considerably greater size than all others. Its uppermost width was 1.5 m and exposed depth was 3 m, where it was covered by colluvium. Projecting its downward taper yielded an estimated concealed depth of 6 m. It too revealed collapse features, including the downward deflection and thinning of host stratification along its margins and a tongue of overlying silt that protruded downward into the upper wedge, as well as a distinct internal fabric.

INTERPRETATION

Salient Characteristics

From the foregoing discussion it is clear that the general characteristics of these features are in part similar to other wedge-shaped structures found in various geologic settings. Although superficially they may resemble any one of several possible structures with a variety of possible origins, a comparison of specific salient characteristics helps to eliminate some alternatives and isolate the most logically related feature(s). Such a comparison is made in table 1.

Crumhorn Mountain and Metcalf-Fitch Hill Sites

Of the various structures listed, only those of the Crumhorn Mountain and Metcalf-Fitch Hill sites and pop-ups are specifically confined to a bedrock host. However, ice-wedge casts do occur in bedrock on occasion (Davies, 1961) and may be confined to existing joints (Black, 1976). Host deformation, size, and filling represent additional similarities between the wedges of these sites and ice-wedge casts. Unfortunately, pop-ups have not been exposed in cross sectional view and a comparison of these characteristics is not possible. Since pop-ups are thought to result from lithostatic unloading, man-made and through deglacial release of stress, it seems reasonable to assume that they would be fairly common features in glaciated regions. Perhaps their subtle expression has for the most part simply gone unnoticed. On the basis of the physical characteristics displayed by the Crumhorn Mountain and Metcalf-Fitch Hill wedges, an association with ice-wedge casts and pop-ups remains equally strong.

One means of testing this association further would be to consider other paleoclimatic indicators for clues to the possibility of permafrost playing a role in the formation of these wedges. In a study of local pollen from bogs in the surrounding terrain, Melia (1975) established a climatic chronology in agreement with previous studies in correlative areas. The pollen record of late glacial time taken from a bog in Maryland, a few miles south of Crumhorn Mountain, consists of A zone (spruce zone) vegetation. Additional pollen data from other localities in the area provide a record of Band C zones (pine and hemlock respectively), which are considered to represent post-glacial conditions. The bedrock wedge structures are considered to have formed during late or post-glacial time because their fillings were derived in part from the overlying till and the deformed bedrock adjacent to the wedges extends upward into the till. If these

TABLE 1 - SUMMARY OF SALIENT CHARACTERISTICS

Wedge Structure	Host	Host Deformation	Width at Top	Depth of Penetration	Filling	Occurrence	Pertinent Associations
Wedges of Crumhorn Mt. & Fitch Metcalf Hill	siltstone, sandstone	flexed & broken upward	generally less than 1m, up to 2m.	2 to 3m.	similar to overlying till, compact strong fabric, collapsed near top	intersect along bedrock joints	filled in part by collapse of overlying till; deformed bedrock extends into overlying till
Wedge of Laurens and Mt. Vision	stratified drift	collapsed downward	generally 5 to 15cm., up to 1.5m.	generally 1 to 2m, up to 6m.	loose drift, with collapse fabric soil tongue	singly, no polygonal pattern noted	proximity to Otego Creek, trend semi-parallel to valley
Ice-wedge cast	drift and bedrock	forced upward	as much as 3m.	as deep as 10m.	varies with setting, slump fabric, evidence of collapse	polygonal pattern	other permafrost features
Sand-wedge	drift	forced upward	8cm to 1.3m	.3m to 3m	structureless sand, vert. oriented crossing sand bands	polygonal pattern	permafrost, but arid conditions
Composite wedge	drift	forced upward	similar to ice-wedge cast	similar ice-wedge cast	composite of ice-wedge and sand-wedge	polygonal pattern	intermediate to ice & sand-wedge
Soil tongue	drift	collapsed downward	less than 1m	as deep as 2 to 3m	loose drift, dis-torted bedding and collapse fabric, soil tongue	circular, linear and branching	soluble carbonate clasts, humid temperate climate
Pop-up	sandstone limestone	flexed & broken upward	overlapping to 1m.	est. to be several meters	not exposed, may not exist	individual linear buckles	unloading of bedrock excavation sites
Tension Crack	stratified drift	collapsed downward	less than 1m.	1 to 2m.	loose drift collapse fabric and soil tongue	singly, linear	host drift undercut by adjacent stream causing mass wasting

structures are a form of ice-wedge cast (or possibly sand wedge or composite wedge) one would expect to find evidence of tundra conditions condusive to ground ice formation represented in the pollen record. This has not been clearly demonstrated, but tundra-like openings within the spruce forest remain a possibility, as pointed out by Melia. The arid conditions necessary for sand wedge formation seems less likely.

Laurens-Mt. Vision Sites

The four most definite aspects of the wedge structures described at these sites are host deformation, size, occurrence, and pertinent associations. As shown in table 1, ice-wedge casts (and related sand and composite wedges), soil tongues, and tension cracks all share a common host material with these structures. The nature of host deformation and size suggest the elimination of any form of ice-wedge cast as a possible origin. Furthermore, the plan view polygonal pattern is also lacking. These structures are,therefore, considered to be of an alternate origin. Of the two remaining possibilities one seems more likely based on occurrence and pertinent associations.

As described by Yehle (1954), soil tongues originate through subsidence as a result of solution and removal of support. The soil tongues he described can occur in a variety of patterns, including linear and branching, but were restricted to outwash with a relatively high carbonate pebble count, such as 66% for the host and 10% within the tongues. While the wedges of the Laurens-Mt. Vision site may be similar in size, shape, and occurrence to soil tongues, they occur in a host that is deficient in soluble calcareous clasts (a few percent or less). However, a comparison with tension cracks described by Black (1976) yields very favorable results. The physical appearance of the wedges, their singular occurrence, and topographic setting all support an origin related to small scale subsidence along tension cracks formed in response to undercutting by an adjacent stream.

SUMMARY

A group of vertically oriented wedge structures are exposed in the walls of four separate excavations in bedrock (sandstone and siltstone) and stratified drift. Two bedrock exposures contain 25 structures that range in width from less than a meter to 2 m. at their tops and taper downward 2 to 3 m. The host adjacent to each is tilted and flexed upward with deformation decreasing with depth. Each wedge generally contains tabular rock fragments held tightly in a fine matrix. Vertical and lateral sorting is expressed by increasing grain size upward and outward. Several display two distinct internal textures consisting of a vertically foliated lower and collapsed upper segment, with sand-size exotics in each. All wedges occur along joints, but their trends do not project upward through an overlying thin lodgement till.

Eleven additional wedge structures were exposed in two closely associated excavations of a deltaic feature. They averaged about 10 cm.

across at their tops and penetrated 1 to 2 m. vertically. However, one much larger structure about 3 times this size was observed. All wedges were characterized by a distinct internal collapse fabric and surficial slump of overlying silty soil. A downward deflection of adjacent host stratification was indicative of subsidence. No surface expression was recognized at either locality and excavation failed to reveal a polygonal orientation.

Although these structures are similar to wedge-shaped features found in regions of past permafrost, there are several other mechanisms of origin that deserve consideration. Similar structures in other parts of New York State and New England have been reported and interpreted to have no particular paleoclimatic significance.

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CAPTIONS

Figure 1. Index map of wedge sites in Otsego County.

Figure 2. Sketches of wedges on Crumhorn Mountain. Illustrated are the salient aspects of the best developed wedges as exposed in 1972. Since then several have been consumed by the quarry operation, but two new ones are currently exposed.

Figure 3. Photograph of wedge on Crumhorn Mountain. Note that the flexed deformation of the bedding is proportional to wedge width and extends into the overlying till. This wedge extended to a depth of about 2 m and could be traced across the quarry floor.

Figure 4. Photograph of wedge on Fitch-Metcalf Hill. This one of two well developed wedges with characteristics similar to those found on Crumhorn Mountain. Note the distinct upward break of host rock as opposed to the flexed deformation in figure 3.

Figure 5. Sketch of wedge at Laurens site. A distinct collapse foliation can be detected within the wedge, as well as in the adjacent host gravel. Note the hand shovel for scale.

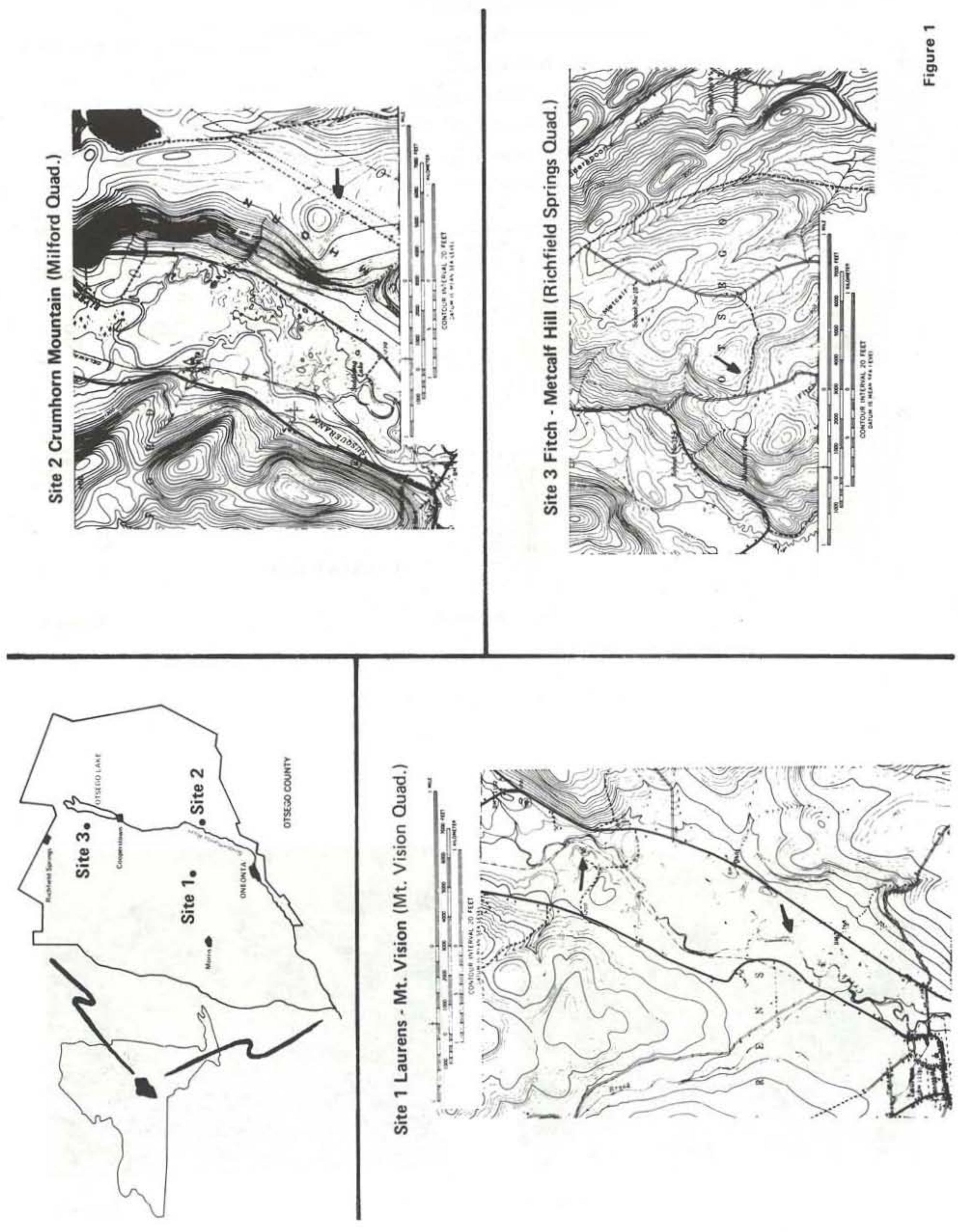
Site 2 Crumhorn Mountain (Milford Quad.)
CONTOUR INTERVAL 20 FEET
Site 3 Fitch - Metcalf Hill (Richfield Springs Quad.)
CONTOUR INTERVAL 20 FEET
Site 1 Laurens - Mt. Vision (Mt. Vision Quad.)
CONTOUR INTERVAL 20 FEET
OTSEGO COUNTY
OTSEGO LAKE
Site 3
Site 2
Site 1
Richfield Springs
Cooperstown
ONEONTA
Morris

Figure 1

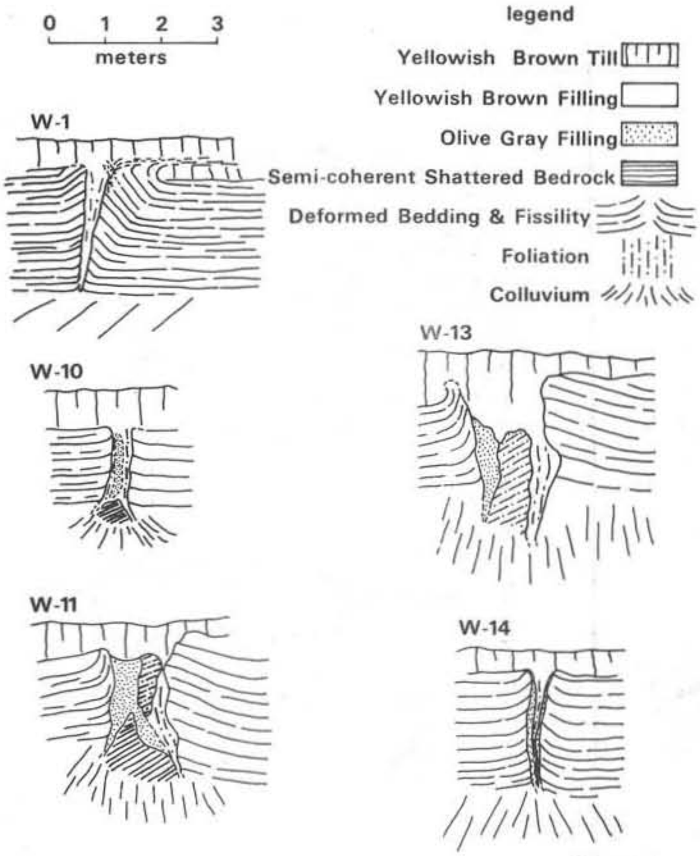

Figure 2

LAURENS SITE

Figure 5

Figure 3

Figure 4

ROAD LOG: WEDGE-SHAPED STRUCTURES IN BEDROCK AND DRIFT

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INTRODUCTION

This log contains a description of the most convenient routes to the wedge localities discussed in the accompanying paper. Specific aspects of each of the three sites are described, but no attempt is made to document the geology between sites. This would be repetitious since the road log in this guidebook entitled Glacial Geomorphology of the Upper Susquehanna Drainage does this in some detail.

This field trip begins at the Route 7-Interstate 88 interchange 2 miles east of Oneonta in the community of Emmons and ends west of Oneonta at the Route 7 - Interstate 88 interchange in what is called the west end.

ROAD LOG

Miles from last point	Cumulative Miles	
0.0	0.0	Proceed east on Rt. 7 and 28 from the traffic light intersection with the I-88 interchange. A notable landmark for this intersection is the Del-Sego Drive-In.
2.5	2.5	Turn left at blinking light. Leave Rt. 7 and follow Rt. 28 north toward Cooperstown. Lorenzo's Homestead Restaurant will be on your left at this intersection.
2.3	4.8	Proceed on Rt. 28 through Milford Center.
1.0	5.8	Enter Portlandville
0.3	6.1	Turn right at Blue Bonnet Antiques on Otsego County Rd. 35, which crosses a bridge (Susquehanna River) immediately and a railroad within 0.2 miles.
0.2	6.3	Just beyond the tracks turn left and remain on County Rd. 35.
0.5	6.8	Turn right at white farmhouse and proceed up Crumhorn Mountain on Wrightman Rd. (unmarked). As the road climbs it provides an impressive view of the Susquehanna Valley.
1.1	7.9	Turn left near top of hill and follow sign that points the way to Boy Scout Camp. This is Boy Scout Rd.

Miles from last point	Cumulative Miles	
0.5	8.4 STOP 1	Pull off to the right near the top of the hill in a bedrock quarry. The Town of Milford uses this rock for fill.

This is the Crumhorn Mountain Site. The quarry operation was much more active in the early 70's when more than a dozen wedge-shaped structures were exposed. Some have since been consumed by the operation or covered under colluvium, but two were well exposed in June, 1977. These can be found east of Boy Scout Road in the south facing wall of the excavation. They are most easily spotted by looking for the upward deformation of the siltstone bedding. Their deepest penetration has not been excavated, but judging from the amount of downward taper they are probably in excess of 2 m deep. These and all others occur along bedrock joints which seem to control their orientation.

Two sets of wooden pegs were emplaced in each of these wedges in order to determine whether their width varied seasonally due to temperature or moisture changes. The upper and lower portions of each wedge were monitored from April, 1976 to the present. The results are as follows:

	Wedge A (nearest the road)	
Date	dist. between upper pegs	dist. between lower pegs
4/21/76	50.0 cm	31.5 cm
5/15/76	50.2 cm	31.5 cm
7/16/76	50.0 cm	31.3 cm
8/17/76	50.0 cm	31.5 cm
9/11/76	49.7 cm	31.6 cm
3/11/77	49.8 cm	31.6 cm
5/31/77	49.8 cm	31.5 cm
	Wedge B (farthest from road)	
4/21/76	36.0 cm	22.2 cm
5/15/76	35.8 cm	22.0 cm
7/16/76	35.6 cm	21.8 cm
8/17/76	35.9 cm	22.0 cm
9/11/76	35.8 cm	22.0 cm
3/11/77	35.4 cm	22.1 cm
5/31/77	35.2 cm	21.9 cm

From these data it is concluded that no seasonal variation alters the width significantly.

The short upper segments of four other wedges may be detected through the colluvium along the east side of the road. Unfortunately,

Miles from last point	Cumulative Miles	
		the most impressive wedge remains buried by debris along the south facing wall of the operation to the west of the road. Most wedges are characterized by a highly compact filling that shows collapse foliation. However, a few small bedrock buckles can be found, in which little or no fill exists. Ice-wedge casts or pop-ups seem to be the main question here. Back track off Crumhorn Mountain to Otsego County Rd. 35.
1.6	10.0	Turn left and back track to Rt. 28.
0.7	10.7	Intersection with Rt. 28. Turn right and proceed north through Village of Portlandville.
4.0	14.7	Village of Milford
0.3	15.0	Blinking traffic light in Milford, proceed north on Rt. 28.
4.9	19.9	Village of Hyde Park
0.5	20.4	Village of Index
2.2	22.6	Village of Cooperstown
0.1	22.7	Bear right across railroad tracks on Rt. 28.
0.4	23.1	Junction of Rt. 28 and 80. Proceed straight on Rt. 80.
0.3	23.4	Traffic light intersection with Main Street. Proceed through intersection
0.1	23.5	Stop sign. Turn left and remain on Rt. 80.
2.0	25.5	Turn left on Otsego County Rd. 28 at Brookwood Point toward Leatherstocking Falls. The planar surface on your right at the turn is the upper surface of a hanging delta that was built into glacial Lake Cooperstown which stood about 20 m above the modern Otsego Lake level. (See paper and road log in this guidebook entitled Glacial Geomorphology of the Upper Susquehanna Drainage).
1.2	26.7	Turn left onto Armstrong Rd. (unmarked, but white house on left and SPCA sign on right).
1.7	28.4	Turn right on Tanner Hill Rd. (unmarked).

Miles from last point	Cumulative Miles	
0.7	29.1	Turn right just beyond large red barn onto Smith Cross Rd. (unmarked). Proceed for 0.2 miles to top of hill.
0.2	29.3 STOP 2	Pull over to the right, outcrop on the left. This is the Fitch-Metcalf Hill Site. There are two main wedges in this outcrop, but several others within walking distance up the road. These wedges are similar in many respects to those on Crumhorn Mountain. They are comparable in size and filling, but associated bedrock deformation appears slightly different. Here the rock is somewhat more massive and less fissile, which may account for why the rock appears broken upward here, as opposed to flexed upward at STOP 1. Here too joints define the orientation of the wedges and the bedrock is veneered by a till that collapsed to contribute to the wedge filling. Other much smaller wedges (or more accurately, buckles) can be seen in another excavation to the right (east). They can be reached by walking along the upper contour of the outcrop, through a raspberry patch and to a shallow excavation about 100 m away, or take the road if you're not a berry fan. Once again we are left with the question of whether these features are frost related or simply reflect the adjustment that occurred due to glacial unloading. Back track to Tanner Hill Rd.
0.3	29.6	Turn right on Tanner Hill Rd. and proceed north.
0.5	30.1	Road ends at intersection with Otsego County Rd. 26. Turn left. Road descends the valley wall of Fly Creek.
1.7	31.8	Bear left and remain on County Rd. 26.
4.0	34.8	Enter Village of Fly Creek. Stop sign at intersection with Rt. 80 and 28. Turn right.
0.7	35.5	Enter Oaksville.
1.7	37.2	Intersection of Rt. 205 south and 80. Turn left on Rt. 205 south and 80 west.
1.9	39.1	Turn left and remain on Rt. 205 south.

Miles from last point	Cumulative Miles	
4.7	43.8	Enter Village of Hartwick, continue south on Rt. 205.
2.2	46.0	Enter Village of Mt. Vision, continue south on Rt. 205.
5.1	51.1	Turn right just before Circle S Farm barn on Blood Mills Rd. (unmarked)
0.3	51.4	Cross Otego Creek bridge and take first right on dirt road that parallels the creek to the north.
0.2	51.7 STOP 3	End of dirt road at gate to Otsego County gravel excavation. This is the first of two locations, collectively referred to as the Laurens-Mt. Vision Site. At various times during the excavation of this deltaic feature (hanging delta or delta kame) massive gravel and sand foreset beds and poorly sorted topset gravels have been exposed. It is within the topset gravel that wedge-shaped structures have been observed. The largest reached a depth of 3 m and was 1 m wide at the top before being destroyed. Several smaller wedges have also been noted. In each case the wedges show a vertical orientation in a general N-S trend. They are characterized by downward collapse that includes the flanking gravels. A pebble count taken here included about 95% local lithologies and less than 1% limestone. However, chert at 1.7% is also present. Since the chert originated in a limestone host, it is assumed that much of the carbonate that was present has been leached. The lack of a polygonal wedge distribution rules out an ice-wedge mechanism for their formation. The evidence for leaching suggest that a soil-tongue forming process may have been active, but in other reported cases the carbonate content was much higher than would be anticipated here. This leaves the tension crack mechanism, which seems to have merit when one considers the juxtaposed location and trend of Otego Creek. Return to Rt. 205
0.4	52.1	Turn right on Rt. 205 south.

Miles from last point	Cumulative Miles	
1.2	53.3 STOP 4	Pull off to the right and walk in to a shallow gravel operation 0.2 miles off highway. This is the second of two localities described as the Laurens-Mt. Vision Site. Repeatedly during the excavation of this site a variety of small wedges, similar to those at the last stop, and vein-like structure (thin wedges) have been exposed. It is assumed that the similarity of features, topographic setting and host material would dictate a similar origin for both localities. Return to Rt. 205 and proceed south.
5.4	58.7	Junction of Rt. 205 with 23 at stop sign and blinking red light. Bear left and proceed south.
1.9	60.6	Traffic light intersection with Rt. 7 at I-88 interchange.

END OF FIELD TRIP